A CLINICALLY USEFUL GAIT ANALYSIS SYSTEM

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Abstract
A gait analysis laboratory can produce temporal, spatial, kinetic and kinematic motion data. While in some experiments, this amount of detail is useful, most patients can be treated with a less detailed analysis. Also this detailed data collection can be quite costly. A typical gait lab consists of expensive cameras, digitisers and force-plates. This equipment is usually non-portable and it is not always possible to have use of the facilities. Hence a low-cost, portable, yet clinically effective gait analysis system was developed. Patients wear surface EMG sensors and footswitches. The sensor information is passed via an optically isolated link to a computer for datalogging and analysis with windows based software. This system is a generic gait analysis tool and does not require an expert operator. It was designed initially to clinically assess the benefits of using Botulinum Toxin, in conjunction with Functional Electrical Stimulation to reduce premature calf activity.

Introduction/Background
Premature calf activity in the terminal swing of gait is an important cause of foot drop in stroke patients [1]. Functional electrical stimulation to correct for dropped foot [2] and the injection of Botulinum Toxin (Botox) to reduce the tone in spastic muscles [3], have both been used successfully in restoring a more normal gait pattern. A study to investigate the two in combination is being conducted at Salisbury District Hospital, UK.

In the clinical environment, assessment of a person’s gait is usually based on visual and subjective techniques. These have limitations, with the literature suggesting that there is a significant difference between visual and quantitative analysis of gait [4-6]. Several authors [7-12] have acknowledged this problem and suggested methods to allow various objective data measurements to be carried out in a clinical environment. This paper proposes a generic computer based quantitative assessment tool to be used in the selection of appropriate patients for this trial and to monitor their progress.

The specification of the system requires the recording of two EMG signals, from Tibialis Anterior and Gastrocnemius, and two footswitch signals, indicating contact of the heel and the first metatarsal head. The use of EMG is acknowledged as a powerful diagnostic technique when treating patients with botulinum toxin [13] and using ratios of muscle activity have been used in quantifying spasticity in these muscle groups [14]. The footswitch data was necessary to relate the EMG data with temporal components of the gait cycle. The system was required to present the sensor data in real time to identify system problems, with off-line processing for spasticity indices, and portable for use outside of the main centre.

Methods
In order to assess the suitability of patients for treatment with Botox, it was necessary to develop a gait analysis system that both acquired and analysed the data. The system would assess the level of calf spasticity in the CVA patients’ lower leg. The spasticity (and its subsequent reduction) can be observed both visually (on the data analysis screen) and objectively with the development of co-contraction indices.

Sensors
Muscle activity from Tibialis Anterior and Gastrocnemius was recorded using MYOPLUS EMG amplifiers (BEAC Biomedical Ltd., Stradella, Italy). The sensor is complete with all filtering, plus hardware
envelope detection and blanking facility. Either the raw EMG or enveloped EMG can be fed to the computer for analysis. By observing the EMG patterns, it was possible to see the activation periods of the different muscle groups.

Footswitch sensors, based on force sensitive resistance (FSR) technology, are used to define key points in the gait cycle. One sensor is placed under the first metatarsal head (to detect the “toe down/rise” events) and the other sensor is placed under the heel (to detect the “heel rise/down” events). Both sensors are worn inside a shoe, under the person’s sock. When viewed with the EMG data, it is possible to build up an accurate representation of the gait cycle.

The system is capable of handling both analog and digital input sensors, though the sensors specified to address the initial requirements of the system were analog EMG and footswitch signals. However, the flexibility of the system allows for the interfacing of other types of sensor, such as goniometers and accelerometers, so that the scope of the system could be extended to investigate other aspects of gait.

PC Interface and Electrical Isolation
A data acquisition card (National Instruments, Texas USA, 1200 DAQ card) is used to input the signals from the sensors to a Pentium II 200 MHz desktop computer. An optical isolation unit provides electrical isolation between the patient and the PC. The isolation unit was designed to operate with different sensors and also interface to an electrical stimulator, to allow the generation of an optically isolated blanking pulse for the EMG sensors.

Data Acquisition and Analysis Software
The software used is Labview 5.1(National Instruments, Texas USA). LabView is a visual program development environment functionally similar to C or Pascal, with strong emphasis on data acquisition and data analysis.

When the analysis software is executed, the clinician is asked (via a dialog box) to ensure the sensors are properly connected and that the isolation unit power is switched on. The main screen allows the user to acquire or analyse data. Choosing the acquire option, the user is then presented with a “real-time” data acquisition window. Here they can see the sensor signals that are connected. They can also set acquisition parameters, such as sampling rate, buffer size etc.

The user can then choose the analysis option on the main menu. This allows the user to open a datalogged file and view its contents. The user can manipulate the data in many different ways, such as: amplifying any of the signals, offsetting the signals, zooming in on the data and placing grid reference lines. If the user is analysing a particular portion of data, it is possible to save this sub-section as a different file. Another option in the ‘acquire’ screen is to calculate gait indices. This function calculates indices such as Premature Calf Activation Index and Push-off Index. The program passes the data to MS Excel using Active X controls. Once the data is passed to MS Excel, a macro is run automatically to calculate the indices and graph the data. A report can then be printed out for clinicians.

The analysis software developed is hardware independent, so that data could potentially be recorded on a different acquisition system and processed using the developed software analysis package.

Results
The developed system is been used to screen and assess patients who are taking part in the Botulinum toxin / FES trial at the Department of Medical Physics and Biomedical Engineering, Salisbury,UK. So far (5) patients have used the system and their data has been successfully recorded and analysed. Using this data it is possible to determine which patients would be most suited to the trial and once they start the prescription of FES and Botulinum injections, their progress can be monitored using the system.

Discussion/Conclusions
The system allows the present trial to be developed further. The inherent flexibility in the design of the system allows for the interfacing of many different types of sensor. Due to the FES blanking facility of the systems EMG sensors, future work will include looking at the effect of FES on muscle activity. The system is a relatively inexpensive but powerful gait analysis tool. It is very portable, as the software can be loaded onto any laptop computer (with a PCMCIA DAQ card) and used anywhere. Using clinicians input in the software design process, the user interface was designed to be straightforward and lucid. There is also a provision for expert users by means of advanced menus.

The system was developed and tested at the Department
of Medical Physics and Biomedical Engineering, Salisbury District Hospital. It is being used in the selection of patients and monitoring of progress, in the trial investigating the effects of using a combined treatment of FES and botulinum toxin injections.

References


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